

1 Disguise and deception of action outcomes through sports garment design impairs
2 anticipation judgments

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21 **RUNNING HEAD: DISGUISE AND DECEPTION**

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Abstract

The ability to disguise and deceive action outcomes was examined by manipulating sports garments. In Experiment 1, those with higher and lower skill levels in anticipation predicted the throw direction of an opponent who wore a garment designed to disguise kinetic chain information. Higher skill anticipators were more adversely affected by the disguise garment than the lower skill anticipators, demonstrating that disguise removed the anticipation advantage. In Experiment 2, using the same occlusion methodology, the effect of deception was examined using two garments designed to create visual illusions of motion across the proximal to distal sequence of the thrower's action and compared to a white garment control. Performances for the deceptive garments were reduced relative to the control garment at the earliest occlusion points for the right-most targets, but this effect was reversed for the left-most targets at the earliest occlusion point, suggesting the visual illusion garments were deceiving participants about motion information from the proximal to distal sequence of the action.

51 Deception and disguise of action outcomes through sports garment design impairs
52 anticipation judgments

53 In fast paced ball sports athletes have to become very sensitive to the movements of
54 opponents in order to find cues to anticipate their intentions. This ability to anticipate
55 provides athletes with more time to move and prepare their response. Point light displays,
56 deprived of surface gradients and textures have been used to show that intentions can be
57 recognized without this information (Abernethy, Gill, Parks, & Packer, 2001; Ward,
58 Williams, & Bennett, 2002). These published reports show that the relative motion profile of
59 the action contains the information upon which intentions can be determined. However, the
60 changing gradient of surface textures may play an important role in determining the
61 kinematics of an opponent, an area not yet investigated in the literature. The skilled
62 advantage in perceiving movement may be prone to break down when fundamental visual
63 processes, such as those frequently described in the literature (Bruce, Green, & Georgeson,
64 2003), are disturbed.

65 In sport, the ability to develop the perceptual-cognitive skills that underpin the
66 recognition of these motion patterns is thought to be a valid and reliable predictor of expertise
67 (Aglioti, Cesari, Romani, & Urgesi, 2008). Therefore, disguising the relative motion of an
68 action may disguise the intentions of an athlete and reduce the advantage afforded by these
69 well-developed perceptual-cognitive skills to chance levels. In two experiments, we examine
70 differences between the effects that deception and disguise have on the anticipation of throw
71 direction. As an alternative to the conventional manipulations used in previous studies, with
72 the aid of computer simulation or willful actions being performed for example, the design of
73 three different garments were altered to disguise advance cues or deceive participants about
74 the motion of body segments. The surface textures and motion of the garment worn by the

75 actor were manipulated based on visual illusions known to effect fundamental visual
76 processes (Bruce et al., 2003).

77 One of the first systematic investigations into deception and disguise in sport
78 examined the ability of skilled and less skilled rugby players to anticipate the direction of an
79 opponent's dribble with and without a deceptive movement (Jackson, Warren, & Abernethy,
80 2006). Less skilled players were found to be more susceptible to deceptive actions than
81 skilled players. The primary focus subsequent to this seminal work has been on deceptive
82 action in soccer (Smeeton & Williams, 2012), tennis (Williams, Huys, Canal-Bruland, &
83 Hagemann, 2009), rugby (Brault, Bideau, Kulpa, & Craig, 2012), and basketball (Sebanz &
84 Shiffrar, 2009). Thus far, there have been only a few published reports focusing on disguise
85 (Rowe, Horswill, Kronvall-Parkinson, Poulter, & McKenna, 2009), presumably due to the
86 methodological difficulties in concealing advance cues without having a consequential effect
87 on linked body segments. Based on the definitions of Jackson et al. (2008) and others (Brault,
88 Bideau, Craig, & Kulpa, 2010), we operationally define disguise as the concealing of genuine
89 advance cues prior to the outcome of an action, such as ball-racket contact. This process is in
90 contrast to deception, which we define as the presentation of counter predictive advance cues
91 to fool an opponent about the outcome of an action. Evidence for disguise, therefore, would
92 be present when a general decrease in anticipation accuracy relative to the control is seen,
93 whereas deception would be evidenced by a reduction in anticipation accuracy that is specific
94 to action outcome (e.g., left or right shot).

95 In two experiments, the surface texture of garments worn by an opponent was
96 changed to either create an unnatural texture gradient cue to disguise an opponent's action
97 outcome, or the illusion of motion to deceive an opponent action outcome. In the first
98 experiment, the disguise manipulation was used to create 'visual noise', where luminance of
99 the dark and light regions across their body changed as the opponent moved (Mather, 2006).

100 In the second experiment, a surface texture based on the Barber pole illusion (Wallach, 1935;
101 (Sun, Chubb, & Sperling, 2015) was used to create a misperception about the movement of
102 an opponent. In this illusion, diagonal straight lines rotating horizontally appear to move
103 vertically. Both manipulations were designed to interfere with the use of genuine advance
104 cues thought to be contained in the kinetic chain present in a thrower's action.

105 **Experiment 1**

106 Published reports investigating advance cues in highly dynamic whole body discrete
107 action have generally concluded that skilled athletes become sensitive to an opponent's
108 movements arising from the kinetic chain (Abernethy, 1993; Abernethy & Zawi, 2007). The
109 Kinematic Specification of Dynamics through biological motion perception presents one
110 conceptual account of these affects (Runeson & Frykholm, 1983). The summation of
111 rotational forces give rise to angular acceleration of body segments towards the end effector
112 originating proximally (to the dominant axis of rotation) and evolving distally. This proximal
113 to distal sequencing has been argued on the basis of evidence from spatial and temporal
114 occlusion and eye movement studies (Smeeton, Huys, & Jacobs, 2013).

115 An alternative to the typical computer simulation approach is to change the perception
116 of the action by making changes to the design of the garments worn by the sports performer.
117 To date, only two published reports have illustrated the use of this approach. It has been
118 reported that altering the properties of sporting garments can either have a facilitating
119 (Causser, McRobert, & Williams, 2013) or debilitating (Causser & Williams, 2015) effect on
120 anticipation judgments. For example, increasing the luminosity of postural cues known to be
121 utilized by athletes detecting teammates' movements led to more accurate and faster
122 anticipation judgments (Causser et al., 2013). Conversely, researchers have shown that by
123 disguising these postural cues by utilizing patterns to offset perceived relative motion,
124 anticipation performance can be significantly reduced (Causser & Williams, 2015). The

125 advantage of this latter approach is that the usual action can still be performed without the
126 characteristic movements of a 'fake' or 'feint'. Sports garments containing visual illusions
127 known to affect fundamental visual processes could give rise to the same misperceptions
128 found in laboratory experiments, and in turn lead to impaired perception of an opponent's
129 kinematics. For example, 'visual skill' by way of the ocular-motor areas of the brain have
130 been shown to activate as a function of anticipation. Greater activation was seen in a network
131 of areas associated with ocular-motor control using fMRI in participants high versus
132 intermediate and low skilled in soccer (Bishop, Wright, Jackson, & Abernethy, 2013).

133 In the first experiment in this paper, perceptually skilled and less-skilled athletes
134 watched video footage of a thrower direct a ball toward a target positioned to their left and
135 right side. The throwing action was occluded at 160ms and 80ms before ball release, at ball
136 release, and 80ms afterwards. The thrower wore two garments. The first garment was
137 designed to effect the perception of angular acceleration by disrupting the extraction of large-
138 scale spatial features (i.e., such as the orientation of the torso). Parallel lines with highly
139 contrasting luminance, well-known to give rise to the perception of edges were printed onto
140 the garment (Mather, 2006). High luminance and low luminance lines were printed on either
141 side of ridges such that, when viewed from the same angle, the movement of the garment,
142 and changing its orientation resulted in changes in the spatial frequency of the edges. This
143 effect was expected to impair the process of spatial filtering known to be an important visual
144 process in the extraction of features (Mather, 2006; Thurman & Grossman, 2011). The
145 second garment was a white t-shirt that acted as a control. It was predicted that throw
146 prediction accuracy in the perceptually skilled would reduce to the level of the perceptually
147 less skilled (i.e., to chance levels) when viewing the 'visual illusion' garment and this effect
148 would be more pronounced at the occlusion points immediately prior to, and at, ball release
149 (i.e., before the availability of ball flight cues).

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Method

Participants and design

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A total of 40 intermediate level netballers (all female; mean age = 24.6 years, SD = 4.5) with a mean playing experience of 6.0 years (SD=3.2) were recruited. Participants watched 160 videos of a similar ability player throw a ball to the left and right side of a camera, filmed to recreate the perspective of an opponent intending to intercept a pass (mean stimulus length = 1960 ms, SD = 90). Footage was occluded at either 160 ms, 80ms before ball release, at ball release or 80 ms after ball release. The thrower wore the visual illusion sports garment designed to disguise the surface texture gradient of the body. This visual information has been shown to be important for visual perception of three dimensional structures (e.g., see Gibson, 1979). In a second condition, the thrower wore a white (control) sports top. Stimulus clips were displayed on a notebook computer screen (1366 x 768 pixels) with a 17 inch screen. The final frame of the occlusion conditions are presented in Figure 1. Both experiments were conducted in accordance with the ethics policy of the institution to which the first author was affiliated.

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Procedure

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For each trial, participants were asked to indicate which direction (left or right) the ball would be thrown by pressing a button on the keyboard. Participants had 1.5 s to respond. The trials were presented in a random order and in 4 blocks of 40 trials. The order of blocks was counter-balanced across participants. For each participant, a percentage accuracy score was calculated based on the number of correct responses for the total number of trials, for each of the four occlusion conditions, for each of the two garments. A within-task criterion was used to create HIGHER and LOWER perceptual-cognitive skills groups based on the

174 total accuracy scores from control condition at the 50th percentile median-split (Bishop et al.,
175 2013; Huys et al., 2009).

176 **Analysis**

177 These data were analysed using a three-way, mixed-design ANOVA with Group
178 (HIGHER, LOWER) as the between-participant factor and Garment (illusion [ILL], Control
179 [CON]) and Occlusion (-160ms, -80ms, 0ms, +80ms) as the within-participant factors.
180 Significant effects were followed up with Bonferroni corrected pairwise comparisons. Partial
181 eta squared (η_p^2) and Cohen’s *r* were used as measures of effect size where appropriate.

182 **Results**

183 Figure 1 shows the effect of the visual illusion sports garment on percent accuracy of
184 throw direction for the HIGHER and LOWER groups across the temporal occlusion points.
185 There was a main effect of Group, $F(1, 38) = 40.70, p < 0.0001, \eta_p^2 = .52$, and Garment, $F(1,$
186 $38) = 15.93, p < 0.001, \eta_p^2 = .30$. On average, participants were 5.0% less accurate when
187 facing the illusion garment than the control. The lower order interactions were superseded by
188 the significant Group x Garment x Occlusion interaction, $F(3, 114) = 7.96, p < 0.0001, \eta_p^2 =$
189 $.17$. In the HIGHER group, accuracy was higher when viewing the visual illusion sports
190 garment compared to the control on the -80ms, 0ms and +80ms occlusions ($p < 0.05$), but not
191 on the -160ms occlusion ($p > 0.05$). In the LOWER group, there were no differences between
192 the visual illusion sports garment and the control garment on any of the occlusion conditions
193 ($p > 0.05$).

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195 **INSERT FIGURE 1 ABOUT HERE**

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Discussion

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We examined the effect of a disguise visual illusion garment on throw prediction accuracy. As predicted, disguising the action outcome using a visual illusion sports garment impaired the perception of cues and reduced judgment accuracy in high-skilled participants. Those with higher skill levels showed decrements in performance at the -80ms, 0ms +80ms occlusion points. These higher skill individuals appear to be particularly sensitive to this motion disguise. Their ability to perceive the outcome of their opponent drops, whereas the less skilled group did not differ. We speculate that the perception of the trajectory of the body movement was impaired by the garment design and as a result the ability of the higher skilled participants to perceive information present in the kinetic chain that would usually be used to anticipate throw direction. This result is consistent with the one previous study investigating disguise through garment design showing skilled anticipators are more susceptible to disguise (Causer & Williams, 2015) and other studies on disguise (e.g. Rowe et al., 2009).

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The manipulation used in this experiment was designed to impair the perception of body movement through known effects of luminance grating changes on spatial filtering. Whilst the approach to examining disguise is consistent with others in the literature, some caution should be adopted in interpreting the results as clear evidence for a disguise effect. There may have been some element of deception present in the stimuli. An analysis that compares accuracies of different throw directions is needed to examine this possibility. To investigate deception a new manipulation was created in order to lead to a misperception of motion, a defining feature of deception. Previously, the presence of kinematic features designed to fool an opponents about an action outcome have been shown to lead to misperception (Brault et al., 2012; Lopes, Jacobs, Travieso, & Araujo, 2014; Smeeton & Williams, 2012). The misperception of specific kinematic features therefore was expected to lead to misperception of action outcomes in Experiment 2.

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Experiment 2

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In Experiment 2, we examine the mechanisms of deception by aiming to alter the perception of motion of the thrower. A previous study investigating anticipation in handball throwers has shown that artificially decoupling left and right body segments impairs anticipation performance in both skilled and less skilled throwers (Bourne, Bennett, Hayes, Smeeton, & Williams, 2013). Therefore, the manipulation aimed to decouple this sequence of the action, and was based on the Barber pole effect (Wallach, 1935). By using this visual illusion as a theoretical backdrop to our manipulation we expected movement perception could be changed and counter-predictive advance cues presented would ‘fool’ opponents about the outcome of an action. The Barber pole illusion leads to the perception of motion tangential to the direction of movement (e.g., vertical motion is perceived from the horizontal rotational movement of a continuous line around cylinder sloping at a 45° to the axis of rotation). The garment was designed to lead to the misperception of the rate of body rotation movement (see Figure 2) such that the horizontal rotation of the hips required to perform the throwing action would be accompanied by a perceived increase in vertical movement. Therefore, more rotational motion would be perceived as vertical motion and as a result, the hips to shoulder linkage would be misperceived to not have rotated as much as they actually had. Based on this rationale, it was expected, that for a right-handed thrower, anticipation accuracy for targets requiring more body rotation (i.e. rightward to the defender facing the thrower) would be decreased relative to the control but not those requiring less rotation (i.e. targets leftward of the defender). Second, another version of the Barber pole illusion manipulation was designed to disrupt the perception of proximal to distal summation of forces through the kinetic chain while controlling for the pattern design. A looser fitting half-t-shirt containing the same pattern was worn over the top of the first that moved more freely across the under t-shirt such that the translation of hip-to-shoulder rotation would be less

248 apparent than the other garment conditions. The effect was expected to dissociate the body
249 rotation in the hip-to-shoulder linkages having the effect of perceiving a delay in the proximal
250 to distal sequence in the kinematic chain while the surface pattern across the two garments
251 did not change. This effect was expected to lead to impaired anticipation accuracy toward the
252 right of the defender, but not targets to the defender's left earlier in the throwing action due to
253 the hips and shoulders being informative for anticipating earlier in the action (Ward et al.,
254 2002; Williams, Ward, Knowles, & Smeeton, 2002). A third white garment acted as a
255 control. Four target location conditions were used to increase the sensitivity to throw
256 direction (Far Left, Near Left, Near Right and Far Right, from the perspective of a defender
257 facing the thrower tasked with intercepting the thrower's pass) and enable measurement of
258 counter predictive advance cues. To further increase the sensitivity of the experiment to the
259 temporal occlusion manipulations higher, medium, and lower skill groups of participants
260 were created. Sensitivity of higher, medium and lower skill groups to deceptive actions has
261 been shown to vary across -160ms, -80ms, 0ms and +80ms occlusion points (Bishop et al.,
262 2013).

263 It was predicted that throw prediction accuracy would be reduced in the visual
264 perception garments relative to the white control garment with the greatest effect seen in the
265 garment that separated the kinetic chain the most because artificially decoupling of body
266 segments has been shown to impair anticipation performance in both skilled and less skilled
267 throwers (Bourne et al., 2013). Additionally, as evidence for deception, we expected
268 decrements in prediction accuracy relative to the control to be specific to throw direction
269 targets. That is, this accuracy would be reduced the most at the rightmost target where the
270 separation of the kinetic chain is thought to be the greatest, and increased the most in the
271 leftmost target where separation is the least. However, if the visual perception manipulation

272 disguised advance cues then this decrement in throw performance would occur uniformly
273 across all target locations.

274 **Method**

275 **Participants and design**

276 The effect of using a visual illusion sports garment to disguise and deceive intention
277 of a netball thrower was compared between netballers with higher, medium and lower
278 perceptual-cognitive skill. A total of 30 intermediate level, netballers (all female; mean age =
279 22.3 years, SD = 3.5) with a mean playing experience of 6.3 years (SD = 2.9) participated.
280 All played for a club and no one played regional standard or above. None of these
281 participants had taken part in Experiment 1. Participants watched 192 videos of a matched
282 ability player throw a ball to Far Left, Near Left, Near Right and Far Right of the camera.
283 The player wore three different garments (see Figure 2). The first two were designed to
284 deceive the opponent about the intended throw direction based on the Barber pole illusion, or
285 the thrower wore a white (control) garment. All other aspects of the design were the same as
286 Experiment 1.

287 **Procedure**

288 For each trial, participants were asked to indicate which direction (Far Left, Near Left,
289 Near Right or Far Right) the thrower would direct the ball. A within-task criterion was used
290 to create HIGHER, MEDIUM, and LOWER perceptual-cognitive skill groups based on the
291 total accuracy scores from control condition at the 33rd percentile median-split. All other
292 procedures were the same as Experiment 1.

293 **Analysis**

294 The accuracy scores (%) were analyzed using a four-way, mixed-design ANOVA
295 with Group (HIGHER, MEDIUM, LOWER) as the between-participant factor and Garment

296 (Body rotation [BODY] Body rotation and kinetic chain [BODY+CHAIN], Control [CON]),
297 Direction (Far Left, Near Left, Near Right or Far Right) and Occlusion (-160ms, -80ms, 0ms,
298 +80ms) as the within-participant factors. Significant effects were followed up with
299 Bonferroni corrected pairwise comparisons. Partial eta squared (η_p^2) and Cohen's r were used
300 as measures of effect size where appropriate.

301

Results

302 There was a main effect of Garment, $F(2,66) = 8.363, p < 0.01, \eta_p^2 = .17$. On
303 average, the lowest accuracy scores were recorded for the BODY+CHAIN visual illusion
304 garment (51.3% SE 1.3) compared to BODY visual illusion (55.0% SE 1.6) and the control
305 garment (56.8%, SE 1.7), $ps < 0.05$. There was a main effect of Direction, $F(3,99) = 17.581,$
306 $p < 0.0001, \eta_p^2 = .347$. On average, participants were significantly more accurate when
307 anticipating throws to the Far Left target (72.7%, SE=3.7) than the Near Left (47.8%,
308 SE=2.4), Near Right (54.7%, SE=2.4) or Far Right targets (42.4%, SE=3.3). No other
309 differences between throw directions were found. There was a main effect of Occlusion
310 $F(3,99) = 77.013, p < 0.0001, \eta_p^2 = .700$. On average, there was a significant difference
311 between -160ms (41.4%, SE=1.1) and -80ms (50.8%, SE=1.4), which in turn was different to
312 0ms (61.6%, SE=1.9), but 0ms was not different to +80ms (63.9%, SE=2.0). There were no
313 significant effects involving Group and the Group main effect was not significant, $F(2,33) =$
314 $0.667, p > 0.05, \eta_p^2 = .039$. However, the Group X Garment X Direction interaction
315 approached the alpha level of significance ($F(8.320,137.281) = 1.979, p = 0.051, \eta_p^2 = .107$.
316 There was a Garment X Direction effect, $F(6,198) = 12.251, p < 0.0001, \eta_p^2 = .271$. This
317 effect showed that throw prediction accuracy for the two visual illusion garments was below
318 that of the control in the Far Right target location and above that of the control in the Far Left
319 target location.

320 Other lower order interactions were superseded by a significant Garment x Direction
321 x Occlusion interaction, $F(18,594) = 3.850, p < 0.0001, \eta_p^2 = .104$. This interaction has been
322 plotted in Figure 3. For throws to the Far Left, early in the action (i.e. -160ms) accuracy for
323 both the BODY and BODY+CHAIN garments were significantly greater than the control.
324 Later in the action the BODY garment was anticipated significantly more accurately than the
325 other two garments (i.e., 0ms). For the Near Left target, no significant differences between
326 garments were seen early in the action (i.e., -160ms to -80ms), but anticipation accuracy in
327 the BODY and BODY+CHAIN garment was significantly lower than the control later in the
328 action (i.e., 0ms). For the Near Right target, accuracy was significantly lower in the
329 BODY+CHAIN garment compared to the BODY and control but not from each other (i.e., -
330 80ms). This BODY+CHAIN difference with BODY and control was no longer found in the
331 later stages of the action (i.e., 0ms to +80ms). Finally, for the Far Right target, both BODY
332 and BODY+CHAIN garments were anticipated with significantly less accuracy than the
333 control particularly in the early stages of the action (i.e., -160ms to -80ms).

334 Discussion

335 We examined the mechanisms of deception by altering the design of the throwers
336 garment. It was predicted that throw prediction accuracy would be reduced in the visual
337 perception garments relative to the white control garment with the greatest effect seen in the
338 garment that effected the perception of the kinetic chain. Additionally, we expected
339 decrements in prediction accuracy relative to the control to be specific to throw direction
340 targets. Overall, the prediction accuracy of the BODY+CHAIN garment was 6% less than the
341 control and 4% less than the BODY garment, indicating the BODY+CHAIN garment lead to
342 successful manipulation of the information used to make throw accuracy predictions.
343 Additionally, there was a Garment X Direction interaction indicating that anticipation
344 performances when viewing the visual illusion garments were below that of the control in the

345 Far Right target location and above that of the control in the Far Left target location. Overall,
346 the relative decline in accuracy when viewing the visual illusion garments was not consistent
347 across the left to right targets relative to the control, suggesting that these visual illusion
348 garments lead to deception rather than disguise. Finally, there was a significant Garment X
349 Target Direction X Occlusion interaction. This 3-way interaction showed that the Garment X
350 Direction interaction effect was more pronounced at the earlier occlusion time points,
351 indicating that the effect resulted from the movement of the thrower prior to ball release.
352 Taking the results of these interactions together, and because the effect was not consistent
353 across throw directions, evidence of a deception effect was found. The most likely cause is
354 that the visual illusion garments lead to misperception of body rotation and information from
355 the movement of forces throughout the kinetic chain. The proximal to distal summing of
356 rotational force leading to the angular acceleration of limb segment is thought to provide
357 important kinematic information for anticipating the resultant direction of a projectile in
358 highly dynamic whole-body actions (Abernethy, 1993; Abernethy & Zawi, 2007).
359 Presumably, the misperception of body rotation and the misperception of the linkage between
360 the rotation of the hips and the shoulders earlier in the action sequence was perceived as the
361 shoulders rotating to a lesser extent, or rotating later in the action, than actually occurred. As
362 a result, more throws were perceived as being directed to the left targets rather than the right
363 ones.

364 Although a skill effect was reported in Experiment 1, there was a non-significant
365 tendency for skill to interact with direction and garment ($F(8.320,137.281)=1.979, p = 0.051,$
366 $\eta_p^2 = .107$). Plausible reasons for a lack of an effect are the change from using a within task
367 criterion to separate groups and the adoption of three, rather than two different skill levels.
368 Additionally, the decoupling of the movement segment between left and right side of the
369 throwers action may have reduced the skill effect. By decoupling the motion of the left and

370 right side of the body by 20% of the total throw time has been shown to reduce the ability to
371 anticipate throw direction of skilled performer to that of less skilled (Bourne et al., 2013).

372 **General Discussion**

373 In this paper, we report two experiments that examined differences between the
374 effects of disguise and deception on the anticipation of throw direction. Three different
375 garments were used with the intention of disguising advance cues or deceiving participants
376 about the motion of body segments. These manipulations were expected to effect the
377 perception of the angular acceleration of body segments resulting from the kinetic chain
378 moving proximal to distal of the end effector. For the first time, the surface textures and
379 motion of the garment worn by the sporting actor were manipulated based on visual illusions
380 known to effect fundamental visual processes (Bruce et al., 2003; Mather, 2006; Sun et al.,
381 2015; Thurman & Grossman, 2011).

382 In Experiment 1, prediction accuracy was reduced in a group of higher skill perceivers
383 to that of a group of lower skill perceivers when they watched a thrower wearing a garment
384 where the rotational movement of the throw resulted in changes in high contrast lines in close
385 proximity to each other. This effect was present -160ms and -80ms before ball release, an
386 effect consistent with other studies containing disguising actions (Causer & Williams, 2015;
387 Rowe et al., 2009). In Experiment 2, it was found that the visual illusion manipulations, based
388 on the Barber pole illusion (Sun et al., 2015; Wallach, 1935), were successful at deceiving
389 perceivers about throw outcome. Accuracy was reduced across throw target locations from
390 left to right in the visual illusion garments, but not in the control garment. Moreover, this
391 effect was more pronounced at earlier occlusion periods, and no large and significant skill
392 effects were found. This is the first investigation of deception using sport garment design, and
393 while others have shown deception to be more pronounced early in the action sequence
394 (Bishop et al., 2013), the use of more sensitive measures by increasing the number of

395 response categories to study deception has allowed the specific effects of the deceptive
396 manipulation to be measured. Such an approach may lead to further insights into the
397 anticipation process as highlighted elsewhere in the literature (Stevenson, Smeeton, Filby, &
398 Maxwell, 2015).

399 This is the first time that the approach used to examine disguise has been compared
400 with deception in one study. The results suggest that there is a qualitative difference between
401 disguise and deceptive advance cues. The disguising of advance cues appears to have more
402 general effects on the perception of advance cues such that the ability to pick up information
403 for anticipation is reduced. There was also a larger effect size for disguising garments $\eta_p^2 =$
404 .30 than deceptive garments $\eta_p^2 = .17$. Whilst direct comparison of the garments is needed,
405 presumably, the information residing in the advance cues is concealed in disguised actions
406 (Brault et al., 2010). In deceptive actions, there is a specific effect on anticipation accuracy
407 such that accuracy is increased to one target location but is reduced in another. The
408 misperception of motion results in the perception of counter-predictive advance cues.
409 Participants are more accurate at anticipating one outcome direction compared to another.
410 This distinction between disguise, which effects all outcome directions, and deception, which
411 effects specific outcomes may provide an objective way of testing between disguise and
412 deception processes, a distinction which still is a source of debate since Jackson et al. (2006)
413 conducted the first systematic study of deception (Jackson et al., 2006). Whilst it is not clear
414 why a skill effect was not found in Experiment 2, one plausible reason is that the
415 experimental manipulation affected fundamental visual processes (the barber pole effect is
416 experienced by many) as a result it may have neutralized, or at least largely diminished the
417 skill effect typically found in the literature. However, a reason for the Group X Garment X
418 Direction effect only approaching significance may have been due to the reduced statistical
419 power resulting from the increase from two groups to three. Alternatively, it may be the case

420 that the within-task criterion used for selecting dichotomous skill groups may result in loss of
421 information. The relationship between anticipation the outcome variables of garment and
422 throw direction may be lost. Some have expressed caution about using this dichotomous
423 approach and recommend a regression analysis to preserve this type of information (Altman
424 & Royston, 2006).

425 These results may have an important practical impact on applied anticipation
426 interventions and research. The typical approach to investigate the informational value of
427 certain body regions for anticipating outcomes is to spatially occlude the region. The
428 resulting effect of this manipulation is that skilled performers then extract information from
429 other regions in order to anticipate outcomes (Huys et al., 2009; Smeeton et al., 2013).
430 However, an important difference between previously published reports and the current
431 approach is that the disguise manipulation reduced performance to that of the less skilled
432 anticipators negating their ability to anticipate even when other body regions were visible.
433 Therefore, when learning to anticipate, the use of occlusion may promote the search for
434 alternative information. However, the use of garments to increase the ambiguity of
435 information may lead to continued impaired performance. Being aware of the occlusion may
436 constrain or facilitate search for alternative regions to extract information, but increasing the
437 ambiguity of the movement of body regions through garment design may not. The use of
438 garments makes it possible to disguise or deceive actions in the absence of intentional
439 movements to do so.

440 Previous approaches to understand disguise and deception have used movements,
441 such as a fake of feint in rugby (Brault et al., 2012) or basketball (Sebanz & Shiffrar, 2009)
442 or exaggeration in soccer (Smeeton & Williams, 2012) or artificially manipulated actions
443 through computer simulation (Huys, Smeeton, Hodges, Beek, & Williams, 2008). The
444 presence of disguise or deceit in the absence of intention to do so may result in a reduced

445 ability of an observer to pick up disguise or deception, thereby increasing the effect of this
446 disguise or deceit. The effect may occur because the observer is not alerted to the disguise or
447 deceit and, as a result, stop the typically observed change from less conscious more conscious
448 awareness, which typically occurs in intentional deception (Jackson et al., 2006; Smeeton &
449 Williams, 2012). For example, when actors intentionally deceive observers, activation of the
450 right anterior cingulate cortex, an area associated with error detection, in the brains of skilled
451 anticipators when viewing deceptive actions has been found to be more active than other
452 lower skill groups (Bishop et al., 2013). Furthermore, brain activations are consistent with the
453 identification of deception in sport requiring more cognitive effort (Wright, Bishop, Jackson,
454 & Abernethy, 2013). What is not known is, when the perception of body movement is
455 changed without the actual movements changing and presumably intentionality not being
456 present then, is this change in awareness absent? If so, then one's normal ability to detect
457 disguise and deception may be impaired.

458 In the case of deception, when a deceiving movement is contained in the action all
459 skill groups are impaired (Brault et al., 2012; Jackson et al., 2006; Smeeton & Williams,
460 2012; Williams et al., 2009). However, the use of deception will typically result in
461 misperception and error monitoring (Bishop et al., 2013). What it not clear is whether or not
462 the use of deceptive visual illusions, that effect 'bottom-up' fundamental visual processes
463 such as feature extraction and motion perception, will result in a performance decline that is
464 impenetrable to 'top-down' processes such as cognitive effort, executive function, and
465 explicit learning. If this impenetrability is found to be correct, then the use of visual illusions
466 in the form of garment design could have a profound effect by neutralizing the expert
467 anticipation advantage they have come to enjoy and, potentially raise questions about the
468 ethics of using these garments in competitive sport.

469 From a practical perspective, the disguise-based garment had a generic effect on
470 anticipation accuracy, whereas deceptive garments impair accuracy to perceive throw
471 direction, but as a consequence increase the accuracy towards another direction. Therefore
472 the impact of the deceptive garments on performance success using this garment pattern is
473 dependent on the throw direction. Similarly, the differences in body rotation direction
474 between left and right arm throwers may reverse the effects of the deception manipulation.
475 The clockwise rotation of the garment for a right-handed thrower produced the misperception
476 of the kinetic chain. It is predicted that if a left-handed thrower was used with a
477 corresponding patterned garment then the opponent directional effect would be found.

478 Whilst this study used netball throwers, it is expected that these effects would be seen
479 in other sports where anticipation of a projectile struck or launched is important for
480 performance. In these sports, such as tennis, football, baseball and cricket, the perception of
481 information for anticipation has been shown to arise from the proximal to distal changes in
482 the opponents kinematics thought arise from the summation of forces across the kinetic chain.
483 A final note of caution is expressed concerning these practical implications. The response
484 mode used in these experiments was a button push and the experimental stimulus was
485 presented on a relatively small two-dimensional computer screen. Some researchers have
486 questioned the ecological validity of these methods (Dicks, Button, & Davids, 2010),
487 although further research is needed to substantiate these claims.

488 In conclusion, we report that both disguise and deception of advance cues can be
489 achieved through modifying the garments worn by athletes. The disguise garment was
490 effective at reducing anticipation accuracy prior to the availability of ball flight, and impaired
491 the perception of advanced cues. The deception garments were successful at causing
492 misperception of advance cues across the kinetic chain leading to a higher anticipation
493 performances for left most targets and lower anticipation performance for right most targets

494 at the earlier time points in the throw. The questions of whether these effects are cognitively
495 impenetrable, and if perceptual-cognitive training can be used to overcome these negative
496 effects, have yet to be addressed and are worthy topics for future research.

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595 lower-skilled players. *Frontiers in Human Neuroscience*, 7. doi:
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Figures

600 *Figure 1.* Judgment accuracy scores from the higher perceptual-cognitive (HIGH) and
601 lower perceptual-cognitive skills (LOW) groups while observing the visual illusion (ILL) and
602 white control (CON) sports garments when stimulus trials were occluded at 160ms, 80ms,
603 0ms before, and 80ms after ball release. The top four panels show the final frame from the
604 ILL condition and bottom the CON condition at the four occlusion points. Error bars
605 represent standard error.

606 *Figure 2.* Stimulus footage across the four occlusion conditions (-160ms, -80ms, 0ms,
607 +80ms) for the three garment conditions (CON=Control, BODY=Body Rotation Illusion,
608 BODY+CHAIN=Body Rotation Illusion and Kinetic Chain Separation).

609 *Figure 3.* The Garment X Occlusion X Direction interaction. The garments are
610 represented by the CON= White garment control, BODY= Barber pole illusion garment and
611 BODY+CHAIN= Barber pole illusion garment with separation of the hips and shoulders.
612 Directions are represented by FL= Far Left, NL= Near Left, NR= Near Right and FR = Far
613 Right target locations. Error bars represent standard error.